las Montañas Rocosas en las décadas de 1960 y 1970. En el año 2004 revisé 15 de los 21 acantilados utilizados por *Falco peregrinus* en el pasado en Colorado para determinar los cambios en la ocupación y en las tasas de productividad. En el año 2004, la tasa de ocupación por pareja fue de un 87% en comparación con un 47% y un 40% entre 1963–65 y 1973–75, respectivamente. La tasa reproductiva basada en todas las parejas con territorios fue de 2.1 juveniles/pareja, en comparación con una tasa de 1.2 y 0.7 para los períodos anteriores, respectivamente. Se estima que 136 parejas nidifican en unos 160 acantilados donde *F. peregrinus* estuvo presente en la última década, pero el número real es seguramente mayor y podría aumentar a 250–400 parejas dada la estimación de la disponibilidad de hábitat apropiado.

[Traducción del equipo editorial]

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ANALYSIS OF RESERVOIR SELECTION BY WINTERING OSPREYS (*PANDION HALIAETUS HALIAETUS*) IN ANDALUSIA, SPAIN: A POTENTIAL TOOL FOR REINTRODUCTION

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KEY WORDS: *Osprey;* Pandion haliaetus; *reintroduction; predictive model; reservoirs; southern Spain; fish production.*

The extant Mediterranean Osprey (*Pandion haliaetus haliaetus*) breeding population is largely fragmented in Morocco, Corsica, and on a few islands from the Balearic and Canary archipelagos, which support isolated-remnant populations (González et al. 1992, Thibault et al. 1996). The disappearance of the Osprey as breeding bird in the coastal region of mainland Spain was due to the loss of suitable nesting sites resulting from the development of a tourist infrastructure (González et al. 1992) and human persecution (especially by theft of eggs or chicks). Ospreys have been extinct as a breeding species in continental Spain since the 1980s (González et al. 1992). However, Ospreys still winter in some parts of Spain. Historically, Andalusia was an important breeding area for this species in Spain, and currently is an important wintering and stopover area for migrant birds (Osterloff 1977, Saurola 1994).

Reservoirs are occupied extensively by breeding Ospreys in most of their range, but they are a relatively new ecosystem in Spain. Reservoirs of 150 ha or more covered 25 500 ha (0.3% of Andalusia) during the 1960s, but now cover twice this area (MOPU 1991). Construction of artificial impoundments may have enhanced the spread of Osprey populations in other areas due to habitat creation (Van Daele and Van Daele 1982, Houghton and Rymon 1997). Reservoirs often provide foraging advantages over rivers and lakes because they are shallow and open-water areas, with reduced turbidity that improve the detectibility of prey (Vana-Miller 1987 and references therein). An

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Osprey reintroduction project involving recently-created reservoirs was initiated in Andalusia in 2003 to re-establish a breeding population on the Iberian Peninsula (Casado and Ferrer 2004).

Requirements of wintering Osprey involve primarily abundance of food supplies (Newton 1979, Prevost 1982), but physical structure of habitat may also affect accessibility to prey (Moore et. al. 1993 and references therein). Fish production or standing crop depends on reservoir features such as mean depth, surface area, shoreline development, water level fluctuation, age, and storage ratio, factors that also affect availability of prey to Osprey (Jenkins 1970, 1976, Sancho Royo and Granados 1988). Also, the quality of a reservoir for a wintering Osprey may be affected by human activity or by the availability of hunting and resting perches. We surveyed structural characteristics, human disturbance, and availability of perches on reservoirs to determine factors affecting occupation by Osprey.

STUDY AREA

Andalusia is the southernmost Spanish autonomous region, with 64 man-made freshwater impoundments ≥150 ha in size, covering a total of 50 183 ha and have a storing capacity of 9403 hm^3 of water. Reservoirs studied were situated among mountains near the seacoast (Betic Chain) and in valleys of the Guadalquivir River and its tributaries. Climate of Andalusia is mild, with maximum and minimum temperatures in winter 20.7°C and −2°C, respectively (Instituto Nacionalde Meterologia 2004). Barbel (*Barbus* spp.), Iberian Nose (*Chondrostoma* spp.), and Carp (*Cyprinus carpio*) are the primary prey species of Osprey in Spanish reservoirs (Sancho Royo and Granados 1988, Gil Sanchez 1995, Lekuona 1998). Predominant vegetation was crop fields in valleys, and pines (*Pinus* spp.) and cork oak (*Quercus suber*) scrub in the mountains. Eucalyptus (*Eucalyptus* sp.) have been planted around reservoirs with recreational facilities.

METHODS

Selection of Reservoirs and Survey of Wintering Osprey. Historical data about presence of wintering Osprey from published sources and from official state reports, from banding centers, wildlife-recuperation centers, and unpublished observations of naturalists and researchers were used to identify occupied reservoirs in our study area. Records of Osprey sightings in the study area between November and mid-March over the winters of 1984–85 to winter 1996–97 were collected.

Systematic surveys on reservoirs were conducted in the winter of 1997–98 (mid-November–mid-March) to investigate the occupancy of each reservoir by Ospreys. Two 45-min Osprey searches were conducted with binoculars (8 × 30) and spotting scope (20 × 60) from different observation points at each reservoir. Searches were conducted by the same observer between 0800–2000 H (solar time). Reservoir searches were conducted with similar weather conditions, avoiding those days with precipitation or high winds, both in the morning and in the evening. One observation point was always at the head of the dam, and the other at the opposite end of the reservoir.

Surveying all of Andalusian reservoirs was not possible due to the limited time of the study period (4 mo in winter). Thus, we had to reduce the sample size to 20 reservoirs which were selected on the basis of previously reported sight records of Osprey. First, 10 reservoirs with previous historical records of wintering Ospreys were chosen. Then, for comparison, we randomly selected 10 reservoirs without previous records of wintering Ospreys.

Habitat Measurements. We collected data on 17 variables possibly affecting both abundance and availability of fish to Ospreys (Table 1). We assumed that shorelines of reservoirs were more likely to be affected by human activity than reservoir centers. Thus, distances from reservoir shoreline to the nearest distribution and transmission power line, nearest paved road, and nearest urban center were measured to provide estimators of human activity.

Other habitat features included in analyses were distance from a reservoir to nearest reservoir >150 ha, distance to nearest coast, and number of arms (thin prolongation of water) of over 100 m length × reservoir $surface^{-1}$ ("number of arms"). Reservoirs on flat terrain usually have few arms, but more large tails than those situated in mountain valleys. Number of reservoir arms was an index of surrounding topographical relief (i.e., higher index values indicated more relief).

Distances, number of arms, and shoreline length were measured on 1:50 000 topographic maps prepared by the Spanish Army Cartographic Service, using a ruler and a digital curvimeter, respectively.

Percent of tree cover within a 20-m wide band around the reservoir edge was considered to be an index of perch availability and was obtained from land-use maps of the Spanish Ministry of Agriculture, using SYGMASCAN pro 4.0 image analysis software (Fox and Ulrich 1995).

Water-exchange rate (the percentage of the difference between the water entry and the water exit, in relation to the mean volume of the reservoir; Table 1) between March 1997 and March 1998 was calculated from data coming from Guadalquivir and south hydrographic confederacies (Spanish Environment Ministry).

Data Analyses. Statistical analyses were conducted using STATISTICA (1986). Variables were transformed (square-root and log [1 + square root]) when necessary to achieve a normal distribution. When variables could not be normalized, nonparametric statistics were used for comparisons. Correlation among variables was evaluated by a factor analysis and covariates were removed. The remaining variables were included in a discriminant function analysis, which was employed to determine the reservoir features that were associated with Osprey presence. Variables for the discriminant analysis were introduced three at a time due to the small sample size. One variable from each of the three factors obtained was included in every entry group in order to avoid co-relations; thus several combinations of variables were analyzed with the discriminant function approach. The forward stepwise method was used and significance was set at $P < 0.05$.

As a measure of the model's ability to predict Osprey occupation of reservoirs, validation was carried out using

Table 1. Comparison of habitat variables between occupied and unoccupied surveyed reservoirs.

	OCCUPIED		UNOCCUPIED		
	N	MEAN	*N*	MEAN	P^a
Meters above sea level	7	10.53	13	11.79	0.362
Years since reservoir construction to winter 1997–98	7	30.29	13	33.85	0.662
Mean surface area (ha)	7	1476.53	13	471.86	0.166
Mean water depth (m)	7	18.14	12	13.31	0.397
Distance from reservoir shoreline to nearest >150 ha reservoir (km)	7	88.31	13	98.94	0.403
Distance from reservoir shoreline to nearest paved road (m)	7	35.71	13	42.31	0.591
Distance from reservoir shoreline to nearest urban center (km)	7	35.30	13	56.39	**0.048**
Distance from reservoir shoreline to nearest distribution power line (m)	7	24.71	13	5.27	0.172
Distance from reservoir shoreline to nearest coast (km)	7	169.30	13	228.92	0.143
Number of arms longer than 100 m in length/reservoir surface (ha)	7	0.16	13	0.23	**0.030**
Shoreline (km)	7	55.41	13	33.86	0.285
Water exchanged, which was calculated by: (entry hm^3 − exit hm^3) × 100/(mean volume hm^3)	7	0.084	13	0.024	0.063
Shoreline development. Ratio of the shoreline length to the circumference of a circle with an area equal to that of the reservoir. Calculated through the function $L/2 \times \sqrt{(\Pi \times A)}$, being L = shoreline length in km, A = area of reservoir (ha)	7	0.40	13	0.43	0.781
Depth where a Secchi disk of 20 × 20 cm was not visible	7	68.44	13	78.35	0.968
Distance from resorvoir shoreline to nearest pole of transmission power line (m)	7	27.01	13	34.27	0.838
Percent of shoreline length occupied for dense canopy	7	3.06	8	1.92	0.270
Trophic state = 10 (6-logD); D = Secchi disk depth	7	−1.96	13	2.35	0.405

[a] Probability that occupied and unoccupied distributions were different was obtained by the Mann-Whitney *U*-test. Probability values in bold indicate statistical significance.

42 more Andalusian reservoirs with previous records of occupation by Osprey.

RESULTS

Twenty reservoirs covering 16 482 ha were included in the analyses (Table 2); these represented 31.25% of reservoirs by number and 33% by surface in Andalusia. According to major operational function, one reservoir was classified as a hydropower reservoir, six as irrigation, nine as municipal water supply, three as recreational use, and one for mining use (MOPU 1991).

Observations of wintering Ospreys in Spain increased from 15 individuals in winter 1984–85 to 47 in winter 1996–97. Of 522 sightings of wintering Osprey in Spain, 400 were from Andalusia. Every Andalusian estuary and marsh was occupied by wintering Ospreys, and 19 out of 64 Andalusian reservoirs were occupied. Seven of the 20 sampled reservoirs were occupied by Osprey.

Altitude (square-root transformed) of reservoirs, age, water-exchange rates (log transformed), shoreline development, water transparency, distances from reservoir shoreline to the nearest distribution and transmission power line, to the nearest paved road, to the nearest urban center, to the nearest reservoir, to the nearest coastal point, square root of number of arms, and percent of tree cover were the non-related variables that were considered for further analysis. Shoreline length (km), mean surface area (ha), concentration of dissolved organic material in water (trophic state), and water depth (m) were redundant and thus, not included in further analysis. Factor analysis provided three principal factors. First, one contributed to 23.77% of total variance and showed the highest factor loading with distance to nearest distribution power line, to nearest reservoir, forest cover, and the transformed index of number of arms and altitude. The second factor explained 18.82% of total variance and was related to water transparency, distance to nearest urban center, and log transformed water-exchange rates. The third factor, which explains 15.81% of total variance, and loaded with age of reservoir, shoreline development,

Table 2. Probability of occupation and presence of Osprey on surveyed reservoirs in Andalusia, Spain.

RESERVOIRS	OSPREY PRESENCE	OCCUPATION PROBABILITY
Agrio	No	0.26
Almodóvar	No	0.33
Arcos	Yes	0.70
Barbate	Yes	0.55
Bornos	Yes	0.70
Cala	No	0.10
Celemín	No	0.03
Charco Redondo	No	0.33
Cordobilla	No	0.55
El limonero	No	0.43
Gergal	No	0.33
Guadalcacín	Yes	0.55
Guadarranque	Yes	0.43
La Concepción	Yes	0.12
La Minilla	No	0.26
Los Hurones	No	0.33
Pintado	No	0.20
Retortillo	No	0.12
Torre del Águila	No	0.43
Zahara	Yes	0.33

nearest distances to transmission power line, to nearest coastal point, and to nearest paved road.

After analyzing several combinations of variables, the simplest discriminant function with the highest correct classification was:

Ln $(P/1 - P) = -6.59259 + 54.30499$(number of arms), which correctly classified 80% of cases: 92.3% of unoccupied reservoirs and 57.1% of occupied (Wilks's Lambda = 0.8, $F_{1,18} = 4.49$, $P < 0.04$). The model clearly discriminated occupied versus unoccupied reservoirs on the basis of number of arms of the reservoir. The reservoirs with the highest probability of occupancy were Arcos ($P = 0.70$), Bornos ($P = 0.70$), Barbate ($P = 0.55$) and Guadalcacín ($P = 0.55$).

To compare univariate differences between occupied and unoccupied reservoirs Mann-Whitney *U*-test was used (Table 1) and these indicated a significant differences in number of arms and distance to nearest urban center. Occupied reservoirs had a fewer number of arms and a shorter distance to nearest urban center.

Validation. Validation with the test set of reservoirs indicated that the discriminate function classified Osprey occupancy well. Only nine (21.4%) of 42 non-surveyed reservoirs were misclassified.

DISCUSSION

The variable number of arms was negatively correlated with Osprey presence both in univariate test and in discriminant function analysis. High topographic relief, reflected by this variable, seemed to be avoided by Osprey Reservoirs with a circular shape are shallower and have higher exchange between the entry and exit of water These factors are associated with higher productivity (Jenkins 1976, Ryder 1982), providing a better food supply to fish-eating birds than those reservoirs located within the mountains. Volume fluctuations enhance nutrient movement, and a greater area of shallow water allows a high production of macrophytes, and consequently, of other organisms including fish. High fish abundance may enhance Osprey foraging efficiency (Flook and Forbes 1983). Deeper water inhibits photosynthesis, depressing primary production (Ryder 1982). Rawson (1952) demonstrated a negative correlation between mean depth and long-term fish production in reservoirs. The same is true for Andalusian reservoirs, where productivity is largely determined by mean depth and the level of eutrophy (Sancho Royo and Granados 1988).

Sancho Royo and Granados (1988) investigated the relationship between fish standing crop and characteristics of seven Andalusian reservoirs, six of which were included in the present study. These authors found that the largest and most shallow reservoirs supported the highest fish density (fish/m^3).

Tolerance of human activity depends on timing, intensity, and frequency of activity and degree of habituation to such activities (Odsjö and Sondell 1976, Swenson 1979, Van Daele and Van Daele 1982, Levenson and Koplin 1984). Occupied reservoirs were closer to an urban center than the unoccupied reservoirs. However, this may be due to topographical constraints when towns were established. No other human-activity indicator was related to occupation by Ospreys, but this result should be taken with caution because we were using data on wintering Ospreys that may respond to human activities in a different way than breeding Ospreys.

Wintering Ospreys in Spanish reservoirs do not appear to choose reservoirs according to foraging perch availability, as also was observed in Senegambia, Africa (Prevost 1982). Areas with high tree coverage will not necessarily be occupied by Ospreys if habitat does not provide an adequate food supply.

In Spain, Ospreys seem to choose reservoirs based on fish productivity over foraging perch availability or human activity. In our analysis, the number of reservoir arms relative to total surface area was identified as a key variable both because it is easy to derive and its relation to reservoir productivity.

Management Implications. Using the discriminant function analysis, we derived an estimate of the probability that one individual would be observed on a reservoir under the conditions that existed during this study This model developed for wintering Ospreys in Andalusia was focused on specific habitat characteristics (e.g., prey and perch availability, human disturbance). Combining this knowledge with an analysis of the status and development plans for the Andalusian reservoirs, environmental management agencies would have an important tool to reduce the threats to migratory and wintering Ospreys.

Results of the present study should be helpful for the Osprey reintroduction project in Spain. One advantage of our model is that the data needed are easily measured from maps, aerial photographs or Geographic Information Systems. The Osprey reintroduction project in Spain has two interesting aspects. First, the program will involve use of reservoirs as release areas that are relatively new man-made habitats. To consider man-induced changes in the environment as new habitat opportunities for endangered species represents a novel approach in conservation. Second, this program can use information about wintering areas as an additional indicator of good-quality habitat for selection of the release areas.

ANÁLISIS DE LA SELECCIÓN DE RESERVORIOS DE AGUA POR *PANDION HALIAETUS HALIAETUS* DURANTE EL INVIERNO EN ANDALUCÍA, ESPAÑA: UNA HERRAMIENTA POTENCIAL PARA LA REINTRODUCCIÓN DE POBLACIONES

RESUMEN.—Se considera que *Pandion haliaetus* es un ave amenazada en el Mediterráneo, donde se encuentra sólo en poblaciones pequeñas y fragmentadas. Las poblaciones reproductivas de esta especie en el área continental de España se extinguieron desde los años ochenta. Sin embargo, España aún representa un área importante de invernada y de escala para las poblaciones migratorias europeas de *P. haliaetus*. En este estudio desarrollamos un modelo de selección de hábitat, en parte para evaluar la factibilidad de reintroducir a esta especie en España. Específicamente, estudiamos la ocupación de reservorios de agua por parte de *P. haliaetus* durante el invierno en Andalucía (sur de España). Comparando características del hábitat de reservorios ocupados y no ocupados, empleamos un análisis discriminante para desarrollar un modelo para predecir la selección de reservorios por esta especie. La función discriminante clasificó correctamente el 80% de los reservorios como ocupados o no ocupados. Los reservorios con mayor probabilidad de estar ocupados por *P. haliaetus* presentaron una forma más circular, menor profundidad general y alta abundancia de peces, y se encontraban a nivel del terreno. Este modelo de predicción podría ser útil para identificar los reservorios óptimos para la reintroducción de individuos nidificantes.

[Traducción del equipo editorial]

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INTRODUCED ANIMALS IN THE DIETS OF THE OGASAWARA BUZZARD, AN ENDEMIC INSULAR RAPTOR IN THE PACIFIC OCEAN

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KEY WORDS: *Common Buzzard;* Buteo buteo toyoshimai; *insular subspecies; diet; introduced animals; Bonin Islands; Ogasawara Islands.*

The Ogasawara buzzard (*Buteo buteo toyoshimai*) is an insular subspecies of the Common Buzzard (*B. buteo*), endemic to the Ogasawara (Bonin) Islands, in the Pacific Ocean (Momiyama 1927, Ornithological Society of Japan 2002). This hawk may be distinguished from a closely-related subspecies, the Japanese Common Buzzard (*B. buteo japonicus*), by its less brown or lighter plumage, a longer bill, and shorter wings and tarsi (Momiyama 1927). The distribution of the Ogasawara buzzard is very restricted, and this hawk is classified as endangered in Japan (Ministry of Environment 2002). Recently, Suzuki and Kato (2000) reported on the abundance of the Ogasawara buzzard on Chichijima, and estimated that less than 85 pairs of this subspecies inhabited the Ogasawara Islands.

Insular raptors are likely to be sensitive to environmental changes as are many other insular predators (e.g., Cade and Jones 1993). Therefore, ecological information including dietary data are needed to develop conservation strategies for the population. However, little information on the food habits of the Ogasawara buzzard are currently available.

Many researchers have investigated the diet of the continental subspecies of the Common Buzzard, especially in Europe. As a result, the Common Buzzard is well known to capture and consume various kinds of invertebrates and small- to medium-sized vertebrates. Common prey include reptiles, birds, and rodents depending on environmental conditions (e.g., Cramp and Simmons 1980, del Hoyo et al. 1994, Jedrzejewski et al. 1994, Swann and Etheridge 1995, Reif et al. 2001, Sergio et al. 2002).

The native fauna of the Ogasawara (Bonin) Islands was originally characterized by low species richness because of the island's volcanic origin, and its small size and relatively great distance from the other islands and mainland of Japan (Tsuyama and Asami 1970). Human colonization of the islands began in the 1830s. After that

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